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(54) Title: A METHOD FOR MANUFACTURING A CABLE (57) Abstract <p>A method for production of an insulated electric DC-cable comprising the steps of extruding a polymer based insulation system comprising a compounded polyethylene around a conductor and subsequently cross-linking the PE composition. The PE composition is pretreated such that the resulting cross-linked PE composition, XLPE, composition, comprises polar groups bonded to the cross-linked structure. Molecular oxygen is, during this pretreatment, introduced into the compounded PE composition prior to the PE composition being extruded from the extruder head.</p>		

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TECHNICAL FIELD

A method for manufacturing a cable

The present invention relates to a method for manufacturing an insulated electric direct current cable, a DC-cable, with a current- or voltage-carrying body, i.e. a conductor and an insulation system disposed around the conductor comprising an extruded and cross-linked polyethylene composition.

The present invention relates in particular to method for manufacturing such a cable suitable for use as an insulated electric DC cable for transmission and distribution of electric power. The extruded insulation system typically comprises a plurality of layers, such as an inner semi-conductive shield, an insulation and an outer semi-conductive shield. At least the extruded insulation comprises a cross-linked polyethylene based electrically insulating composition with a system of additives typically comprising cross-linking agent, scorch retarding agent and anti-oxidant.

BACKGROUND ART

Although many of the first electrical supply systems for transmission and distribution of electrical power were based on DC technology, these DC systems were rapidly superseded by systems using alternating current, AC. The AC systems had the desirable feature of easy transformation between generation, transmission and distribution voltages. The development of modern electrical supply systems in the first half of this century was exclusively based on AC transmission systems. However, by the 1950s there was a growing demand for long transmission schemes and it became clear that in certain circumstances there could be benefits by adopting a DC based system. The foreseen advantages include a reduction of problems typically encountered in association with the stability of the AC-systems, a more effective use of equipment as the power factor of the system is always unity and an ability to use a given insulation thickness or clearance at a higher operating voltage. Against these very significant advantages has to be weighed the high cost of the terminal equipment for conversion of the AC to DC and for inversion of the DC back again to AC. However, for a given transmission power, the terminal costs are constant and therefore, DC transmission systems were rendered

economical for the schemes involving long distances. Thus DC technology becomes economical for systems intended for transmission over long distances as for when the transmission distance typically exceed the length for which the savings in the transmission equipment exceeds the cost of the terminal plant.

An important benefit of DC operation is the virtual elimination of dielectric losses, thereby offering a considerable gain in efficiency and savings in equipment. The DC leakage current is of such small magnitude that it can be ignored in current rating calculations, whereas in AC cables dielectric losses cause a significant reduction in current rating. This is of considerable importance for higher system voltages. Similarly, high capacitance is not a penalty in DC cables. A typical DC-transmission cable include a conductor and an insulation system comprises a plurality of layers, such as an inner semi-conductive shield, an insulation base body and an outer semi-conductive shield. The cable is also complemented with casing, reinforcement etc to withstand water penetration and any mechanical wear or forces during, production installation and use.

Almost all the DC cable systems supplied so far have been for submarine crossings or the land cable associated with them. For long crossings the mass-impregnated solid paper insulated type cable is chosen because there are no restrictions on length due to pressurizing requirements. It has been supplied for operating voltages of 450 kV. To date an essentially all paper insulation body impregnated with a electric insulation oil has been used but application of laminated material such as a polypropylene paper laminate is being persued for use at voltages up to 500 kV to gain advantage of the increased impulse strength and reduced diameter.

As in the case of AC transmission cables, transient voltages is a factor that has to be taken into account when determining the insulation thickness of DC cables. It has been found that the most onerous condition occurs when a transient voltage of opposite polarity to the operating voltage is imposed on the system when the cable is carrying full load. If the cable is connected to an overhead line system, such a condition usually occurs as a result of lightning transients.

Extruded solid insulation based on a polyethylene, PE, or a cross linked polyethylene, XLPE, has for almost 40 years been used for AC transmission and distribution cable insulation. Therefore the possibility of the use of XLPE and PE for DC cable insulation has been under investigation for many years. Cables with such insulations have the same advantage as the mass impregnated cable in that for DC transmission there are no restrictions on circuit length and they also have a potential for being operated at higher temperatures. In the case of XLPE, 90°C instead of 50°C for conventional DC-cables. Thus offering a possibility to increase the transmission load. However, it has not been possible to obtain the full potential of these materials for full size cables. It is believed that one of the main reasons being the development and accumulation of space charges in the dielectric when subjected to a DC-field. Such space charges distort the stress distribution and persist for long periods because of the high resistivity of the polymers. Space charges in an insulation body do when subjected to the forces of an electric DC-field accumulate in a way that a polarized pattern similar to a capacitor is formed. There are two basic types of space charge accumulation patterns, differing in the polarity of the space charge accumulation. The space charge accumulation results in a local increase at certain points of the actual electric field in relation to the field, which would be contemplated when considering the geometrical dimensions and dielectric characteristics of an insulation. The increase noted in the actual field might be 5 or even 10 times the contemplated field. Thus the design field for a cable insulation must include a safety factor taking account for this considerably higher field resulting in the use of thicker and/or more expensive materials in the cable insulation. The build up of the space charge accumulation is a slow process, therefore this problem is accentuated when the polarity of the cable after being operated for a long period of time at same polarity is reversed. As a result of the reversal a capacity field is superimposed on the field resulting from the space charge accumulation and the point of maximal field stress is moved from the interface and into the insulation. Attempts have been made to improve the situation by the use of additives to reduce the insulation resistance without seriously affecting other properties. To date it has not been possible to match the electrical performance achieved with the impregnated paper insulated cables and no commercial polymeric insulated DC cables have been installed. However, successful laboratory tests have been reported on a 250 kV cable with a maximum stress of 20 kV/mm using XLPE insulation with mineral filler (Y.Maekawa et al, Research and Development of DC XLPE Cables, JiCa-

ble'91, pp. 562- 569). This stress value compares with 32 kV/mm used as a typical value for mass-impregnated paper cables.

An extruded resin composition for AC cable insulation typically comprises a polyethylene resin as the base polymer complemented with various additives such as a peroxide cross-linking agent, a scorch retarding agent and an anti-oxidant or a system of antioxidants. In the case of an extruded insulation the semi-conductive shields are also typically extruded and comprise a resin composition that in addition to the base polymer and an electrically conductive or semi-conductive filler comprises essentially the same type of additives. The various extruded layers in an insulated cable in general are often based on a polyethylene resin. Polyethylene resin means generally and in this application a resin based on polyethylene or a copolymer of ethylene, wherein the ethylene monomer constitutes a major part of the mass. Thus polyethylene resins may be composed of ethylene and one or more monomers which are co-polymerisable with ethylene. LDPE, low density polyethylene, is today the predominant insulating base material for AC-cables. To improve the physical properties of the extruded insulation and its capability to withstand degradation and decomposition under the influence of the conditions prevailing under production, shipment, laying, and use of such a cable the polyethylene based composition typically comprises additives such as;

- stabilizing additives, e.g. antioxidants, electron scavengers to counteract decomposition due to oxidation; radiation etc.;
- lubricating additives, e.g. stearic acid, to increase processability;
- additives for increased capability to withstand electrical stress, e.g. an increased water tree resistance, e.g. polyethylene glycol, silicones etc.; and
- cross-linking agents such as peroxides, which decompose upon heating into free radicals and initiate cross-linking of the polyethylene resin, sometimes used in combination with
- unsaturated compounds having the ability to enhance the cross-linking density;
- scorch retarders to avoid premature cross-linking.

The number of various additives is large and the possible combinations thereof is essentially unlimited. When selecting an additive or a combination or group of additives the aim is that one or more properties shall be improved while others shall be maintained or if possible also

improved. However, in reality it is always next to impossible to forecast all possible side effects of a change in the system of additives. In other cases the improvements sought for are of such dignity that some minor negative have to be accepted, although there is always an aim to minimize such negative effects.

A typical polyethylene based resin composition to be used as an extruded, cross-linked insulation in an AC-cable comprises:

97,1 - 98,9 % by weight of low density polyethylene (922 kg/m^3), melt flow rate of 0,4 - 2,5 g/10 min with a system of additives as described in the foregoing.

These additives can comprise:

0,1 - 0,5 % by weight of an antioxidant such as but not limited to SANTONOX R® (Flexsys Co) with the chemical designation 4,4'-thio-bis(6-tert-butyl-m-cresol), here referred to as compound (A) and

1,0 - 2,4 % by weight of a cross linking agent such as but not limited to , DICUP R® (Hercules Chem) with the chemical designation dicumyl peroxide.

Although some disadvantages with the use such an XLPE composition have been known for a long time its advantages (e.g. its ability to prevent scorch i.e. premature cross linking) have outweighed these drawbacks. Furthermore it is well known that this type of XLPE composition exhibits a strong tendency to form space charges under DC electric fields, thus making it unusable in insulation systems for DC cables. However, it is also known that extended degassing ,i.e. exposing the cross linked cable insulation at high temperatures to a high vacuum for long periods of time, will result in a somewhat decreased tendency to space charge accumulation under DC voltage stress. It is generally believed that the vacuum treatment removes the peroxide decomposition products, such as "acetophenone" and "cumyl alcohol", from the insulation whereby the space charge accumulation is reduced. Degassing is a time-consuming batch-process comparable with impregnation of paper insulations and thus as costly. Therefore it is advantageous if the need for degassing is removed. Most known cross-linked polyethylene compositions used as extruded insulation in AC-cable exhibit a tendency for space charge accumulation which renders them unsuitable for use in insulation systems for DC-cables.

It is known to add low amounts of an additive comprising carbonyl groups to a LDPE for the dual purpose of increasing resistivity and decreasing space charge accumulation. Such addition of carbonyl is accomplished by a copolymerization of carbon monoxide with ethylene. The carbonyl groups are believed to act as trap sites for space charges, whereby the mobility of any space charges is restricted and the development of a polarized pattern within the cross-linked insulation as a result of space charge accumulation when the insulation is subjected to a DC-field. However a tendency for detrapping and thereby an increased space charge accumulation has been noted at elevated temperatures, e.g. temperatures above about 40°C. Further molar modifications of the polyethylene has been suggested by introduction of polar units into the polymer to obtain a higher DC-breakdown strength. For example Japanese Patent Publication JP-A-210610 reports that an anhydride such as Maleic Acid Anhydride, MAH, have been grafted onto the polyethylene for this purpose. The resulting cross-linked insulation material exhibited a decrease in space charge accumulation attributed to the increased polarity of the cross-linked polymer chain structure and it was concluded that the grafted MAH groups, which are fixed within the cross-linked structure, acts as trap sites for any space charges. In JP-A-210610 it was also reported that cross-linked polyethylene with additions of MAH at levels corresponding to from about 0.02 to about 0.5 % by weight resulted in cross-linked composition suitable for use as insulation in a DC-cable with a decreased space charge accumulation. Other additions used for such polar modification of the cross-linked structure and associated reduction in space charge accumulation in the cross-linked insulation is ionomers, acrylic metal salts, carboxylic acid and acetates.

Thus it is desirable to provide a process for production of an insulated DC-cable with an extruded polymer based electrical insulation system suitable for use as a transmission and distribution cable in networks and installations for DC transmission and distribution of electric power. The process for application and processing of then extruded insulation system shall preferably be carried out in a manner such that there is no need for any lengthy time consuming batch-treatment (e.g. vacuum treatment) of the cable to ensure stable and consistent dielectric properties and a high and consistent electric strength of the cable insulation. The resulting cable insulation shall further exhibit a low tendency to space charge accumulation, a high DC breakdown strength, a high impulse strength and high insulation resistance. The

adoption of such a process would offer both technical and economical advances over prior art methods as production time and production costs can be reduced and the possibility for an essentially continuous or at least semi-continuous process for the application and processing of the cable insulation system is provided. Further the process shall ensure that the reliability, the low maintenance requirements and the long working life of a conventional DC-cable, comprising an impregnated paper-based insulation, shall be maintained or improved. The replacement of an impregnated paper or cellulose based insulation with an extruded polymeric insulation shall as an extra advantage open for an increase in the electrical strength and thus allow an increase in operation voltages, improve handleability and robustness of the cable. In particular the extruded and cross-linked PE composition contained in the insulation system shall be applied and processed such that the cross-linked three dimensional cross-linked structure exhibit trap sites for space charges, whereby the mobility of any space charges is restricted and the development of a polarized space charge profile within the extruded insulation. Such a reduction in the tendency for space charge accumulation in the insulation provides as an extra economical advantage a capability to reduce safety factors in design values used for dimensioning the cable insulation. A cable as defined in the foregoing paragraphs shall be suitable for operation under the specific conditions prevailing in high-voltage transmission or distribution cable used in a network or installation for transmission or distribution of electrical power.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for production of an insulated electric DC-cable as specified in the foregoing. This is according to the present invention achieved by a method as defined in the preamble of claim 1 for the manufacture of an insulated DC cable having a polymer based insulation system comprising an extruded cross-linked polyethylene composition disposed around a conductor characterized by the further measures according to the characterizing part of claim 1. Further developments of the invented method are characterized by the features of the additional claims 2 to 13.

DESCRIPTION OF THE INVENTION

This is for a method for production of an insulated electric DC-cable comprising the steps of extruding a polymer based insulation system comprising a compounded polyethylene composition, PE composition, around a conductor and subsequently cross-linking the PE composition, wherein the PE composition is pretreated such that the resulting cross-linked PE composition, XLPE composition, comprises polar groups bonded to the cross-linked structure accomplished by the introduction of molecular oxygen into the compounded PE composition prior to the PE composition being extruded from the extruder head.

According to one embodiment the molecular oxygen is introduced into the compounded PE composition in a pretreatment prior to the PE composition being introduced to the extruder head. Typically the PE composition is, in the form of PE granules, fed into the extruder and the molecular oxygen is introduced into the PE-granules in a pretreatment prior to being introduced to the extruder head. Preferably the pretreatment according to this embodiment is carried out in a special container associated with the extruder feeding system or within the feeding system prior to the extruder head.

According to one alternative embodiment the molecular oxygen is introduced into the compounded PE composition in a pretreatment within the extruder. Also in this cases the PE composition is present in the form of granules, which is fed into the extruder. Alternatively the molecular oxygen is introduced into the PE-melt in the extruder during the extrusion process.

The solubility of molecular oxygen in polyethylene (50% crystallinity) is of the order of $0,05 \text{ cm}^3(\text{STP})/\text{cm}^3 \text{ bar}$. This means that polyethylene in equilibrium with atmosphere air (21% oxygen) will contain approx. $0,01 \text{ cm}^3 \text{ oxygene}/\text{cm}^3 \text{ polyethylene}$. This amount of oxygen will be dissolved in the molten PE after extrusion.

During the cross-linking reaction the peroxide will decompose and form free-radicals. The free-radicals will attack the polymer molecules and form polymer free radicals. The reaction between the polymer free radicals and the molecular oxygen is very fast as a result of the

presence of two impaired electrons in the molecular oxygen in its ground state. This makes oxygen behave as a bi-radical and its reaction with polymer free radicals can be compared to reactions between two radicals. These reactions are characterized by very low activation energy. The product of the reaction between a polymer free radical and an oxygen molecule is peroxy-radical. The most probable termination reaction of primary and secondary peroxy radicals is disproportional to alcohols and aldehydes or to alcohols ketones, respectively. These alcohols, aldehydes and ketones being polar moieties. If all oxygen dissolved in the PE in equilibrium with atmospheric air react in the above manner one polar moiety per 100 000 monomer units will be formed.

The solubility of oxygen in PE is proportional to the partial pressure of oxygen. Hence, by increasing the pressure the amount of oxygen dissolved will increase and hence the number of polar moieties. The number of polar moieties can be controlled solely by controlling the amount of dissolved oxygen. E.g. at an oxygen pressure of 2 bar the number of polar moieties will be approx. one per 10 000 monomer units.

To achieve an effect on the space charge accumulation the number of polar moieties should be greater than one per 50 000 monomer units corresponding to an equilibrium with air, oxygen partial pressure of 0,4 bar.

To introduce the required number of the oxygen molecules into the PE-composition the PE composition is subjected to an increased oxygen pressure. This can be achieved by increasing the partial pressure of any oxygen containing atmosphere in contact with the PE composition, at the stages suitable for introduction of molecular oxygen into the PE composition. Typically the PE composition is subjected to an oxygen pressure, pO_2 exceeding 0,2 bar but lower than 20 bar. Preferably the PE composition is subjected to an oxygen pressure, pO_2 of from 0,4 to 5 bar.

The method is typically carried out in such a manner that the oxygen at least initially is dissolved in the PE composition. According to one embodiment the PE composition comprising dissolved oxygen is thereafter conditioned in association with the extrusion and cross-linking

of the insulation system such that the dissolved oxygen is reacted with the PE composition and polar groups is introduced in the three dimensional network formed in the cross-linked PE composition.

The compounded polyethylene based insulation is typically extruded and cross linked at an elevated temperature and for a period of time long enough to cross link the insulation.

A DC cable produced according to the present invention with an extruded, cross linked insulation system comprising a cross-linked polyethylene composition, XLPE, with the specific processing mentioned above exhibit considerable advantages such as;

- A substantially reduced tendency for space charge accumulation resulting in low tendency for development of a polarized space charge profile,
- An increased DC breakdown strength.

The process according to the present invention offers the possibility of an essentially continuous or semi-continuous process for the application and processing of the extruded insulation system without any need for batch treatments, such as degassing or impregnation to ensure the performance and stability of the extrude cable insulation system.

All these advantageous properties and improvements over cables produced with prior art processes for production of cables comprising an insulation system with an extruded XLPE composition, is for a DC-cable produced according to the present invention achieved without the many disadvantages associated with some cables produced with prior art process. The substantially reduced tendency for space charge accumulation ensures that the high DC breakdown strength of conventional DC-cables comprising an impregnated paper insulation is maintained or improved. Further the insulating properties of a DC-cable produced according to the present invention exhibit a general long term stability such that the working life of the cable is maintained or increased. This achieved in particular by the controlled processing of the PE composition prior to and during extrusion and cross-linking and the conditioning carried out in association with the extrusion and cross-linking, wherein process variables such as temperatures, pressures, processing times, atmosphere composition and in particular the par-

tial pressure of oxygen or other gaseous molecules that are likely to be dissolved in the PE composition according to the invention as will be exemplified in the coming.

The process according to the present invention offers the capability to produce a DC-cable with a solid dielectric in an essentially continuous process without any time consuming batch step such as degassing, thereby opening for substantial reduction in production time and thus the production costs without risking the technical performance of the cable.

A DC cable produced with a process as defined in the foregoing is especially advantageous for operation under the specific conditions prevailing in high-voltage transmission or distribution cable used in a network or installation for transmission or distribution of electrical power, due to the improved thermal properties combined with maintained or improved electrical properties. This is especially important due to the long life such installations are designed for, and the limited access for maintenance to such installations of being installed in remote locations or even sub-sea. One further advantage for a high-voltage direct current cable produced according to the present invention is that the production time can be substantially reduced by the adoption of an essentially continuous process free from operating steps requiring batch treatment of complete cable lengths or part lengths offer cost advantages compared to conventional cables.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention shall be described more in detail while referring to the drawings and examples. Figure 1 shows a section-view of a cable for high-voltage direct current transmission of electric power according to one embodiment of the present invention. Figure 2 shows an out line of a process for applying an insulation system comprising an extruded and cross-linked polyethylene composition to a cable.

The DC-cable according to the embodiment of the present invention shown in figure 1 comprises from the center and outwards;

- a stranded multi-wire conductor 10;

- a first extruded semi-conducting shield 11 disposed around and outside the conductor 10 and inside a conductor insulation 12;
- an extruded conductor insulation 12 with an extruded, cross-linked composition as described in the foregoing;
- a second extruded semi-conducting shield 13 disposed outside the conductor insulation 12;
- a metallic screen 14; and
- an outer covering or sheath 15 arranged outside the metallic screen 14.

The cable can when deemed appropriate be further complemented in various ways with various functional layers or other features. It can for example be complemented with a reinforcement in form of metallic wires outside the outer extruded shield 13, a sealing compound or a water swelling powder introduced in metal/polymer interfaces or a system of radial achieved by e.g. a corrosion resistant metal polyethylene laminate and longitudinal water sealing achieved by water swelling material, e.g. tape or powder beneath the sheath 15. The conductor need not be stranded but can be of any desired shape and constitution, such as a stranded multi-wire conductor, a solid conductor or a segmental conductor.

In the process shown in figure 2 the conductor is fed from a conductor pay-off 26 through the extruder equipment 21, 22, 23 and other processing and conditioning devices 24, 25 and is finally taken up on a cable core take-up 27. The conductor pay-off 26 and cable core take-up is in figure 2 illustrated as reels or drums suitable for discrete lengths but can be of any suitable type including devices for essentially continuous handling of the supplied conductor and produced cable. The conductor is passed over a first wheel 28 through a conductor preheater wherein it is preheated for a suitable temperature before the insulation system is applied by extrusion. The process shown in figure 2 is suitable for true triple extrusion where a triple head extruder is used. The inner and outer semi-conductive layers are applied using two separate extruders 22 and a further third extruder is used for the main insulation. After the extrusion operation the insulated cable is passed through a pressurized curing and cooling chamber 24, wherein the conditions is controlled to ensure the desired cross-linking degree and other structural characteristics that can be effected by this controlled conditioning and cooling of the extruded insulation system. Thereafter the cable is hauled through a haul-off

caterpillar 30 and over a second wheel before being taken up for further processing and/or shipment.

The polyethylene composition used is typically supplied to the extruder as a granulate which is fed through a feeding system 210. Molecular oxygen is introduced into the compounded PE granulate in a pretreatment prior to the PE being introduced to the extruder 21 or in a pretreatment within the extruder 21. Alternatively the molecular oxygen is introduced into the PE-melt in the extruder 21 during the extrusion process. Typically the PE granules are fed into the extruder and melted.

The pretreatment can be carried out in a special container associated with the extruder feeding system 210 or within any of the existing parts 211, 212, of the feeding system 213 or the extruder 21. Typically the PE composition is subjected to an oxygen pressure, p_{O_2} exceeding 0,2 bar but lower than 20 bar in the feeding system 210 or the extruder 21 to introduce the required amount of oxygen into the PE composition. The solubility of molecular oxygen in polyethylene (50% crystallinity) is of the order of $0,05 \text{ cm}^3 \text{ (STP)/cm}^3 \text{ bar}$. This means that polyethylene in equilibrium with atmosphere air (21% oxygen) will contain approx. $0,01 \text{ cm}^3$ polyethylene. This amount of oxygen will be dissolved in the molten PE after extrusion. According to one specific embodiment the PE composition is subjected to an oxygen pressure, p_{O_2} of from 0,4 to 5 bar. The method is typically carried out in such a manner that the oxygen at least initially is dissolved in the PE composition and the PE composition comprising dissolved oxygen is thereafter conditioned in association with the extrusion and cross-linking of the insulation system such that the dissolved oxygen is reacted with the PE composition and polar groups is introduced in the three dimensional network formed in the cross-linked PE composition. The compounded polyethylene based insulation is typically extruded and cross linked at an elevated temperature and for a period of time long enough to cross link the insulation. This is achieved by controlling the processes in the extruder 21, extruder head 23 and the pressurized curing and cooling chamber 24 in a suitable way as suggested in the foregoing.

A DC cable produced according to the present invention with an extruded, cross linked insulation system comprising a cross-linked polyethylene composition, XLPE, with the specific processing mentioned above exhibit considerable advantages such as;

- A substantially reduced tendency for space charge accumulation resulting in low tendency for development of a polarized space charge profile,
- An increased DC breakdown strength.

The process according to the present invention offers the possibility of an essentially continuous or semi-continuous process for the application and processing of the extruded insulation system without any need for batch treatments, such as degassing or impregnation to ensure the performance and stability of the extrude cable insulation system.

CLAIMS

1. A method for production of an insulated electric DC-cable comprising the steps of extruding a polymer based insulation system comprising a compounded polyethylene composition, PE composition, around a conductor and subsequently cross-linking the PE composition, wherein the PE composition is pretreated such that the resulting cross-linked PE, XLPE, composition, comprises polar groups bonded to the cross-linked structure, **characterized** in that molecular oxygen is introduced into the compounded PE composition prior to the PE composition being extruded from the extruder head.
2. A method according to claim 1, **characterized** in that the molecular oxygen is introduced into the compounded PE composition in a pretreatment prior to being introduced to the extruder head.
3. A method according to claim 1 or 2, **characterized** in that the PE composition in the form of granules is fed into the extruder and that the molecular oxygen is introduced into the PE-granules in a pretreatment prior to being introduced to the extruder.
4. A method according to claim 3, **characterized** in that the pretreatment is carried out in a special container associated with the extruder feeding system.
5. A method according to claim 1 or 2, **characterized** in that the molecular oxygen is introduced into the compounded PE composition in a pretreatment within the extruder.
6. A method according to claim 5, **characterized** in that the PE composition in the form of granules is fed into the extruder and that the molecular oxygen is introduced into the PE-granules within the extruder feeding system.
7. A method according to claim 5, **characterized** in that the PE composition in the form of granules is fed into the extruder, that the PE granules are melted in the extruder and that the molecular oxygen is introduced into the PE-melt.

8. A method according to any of the preceding claims, **characterized** in that the PE composition is subjected to an increased oxygen pressure.
9. A method according to claim 8, **characterized** in that the PE composition is subjected to an oxygen pressure, pO_2 exceeding 0.2 bar.
10. A method according to claim 9, **characterized** in that the PE composition is subjected to an oxygen pressure, pO_2 of from 0.4 to 5 bar.
11. A method according to any of claims 8 to 10, **characterized** in that the PE composition is subjected to an oxygen enriched atmosphere.
12. A method according to any of the preceding claims, **characterized** in that the oxygen is dissolved in the PE composition.
13. A method according to any of the preceding claims, **characterized** in that the PE composition comprising dissolved oxygen is conditioned in association with the extrusion and cross-linking of the insulation system such that the dissolved oxygen is reacted with the PE composition and polar groups is introduced in the three dimensional network formed in the cross-linked PE composition.

1/2

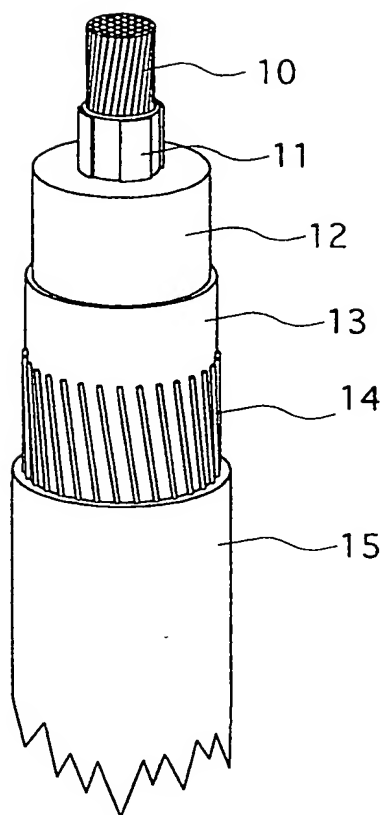


Fig 1

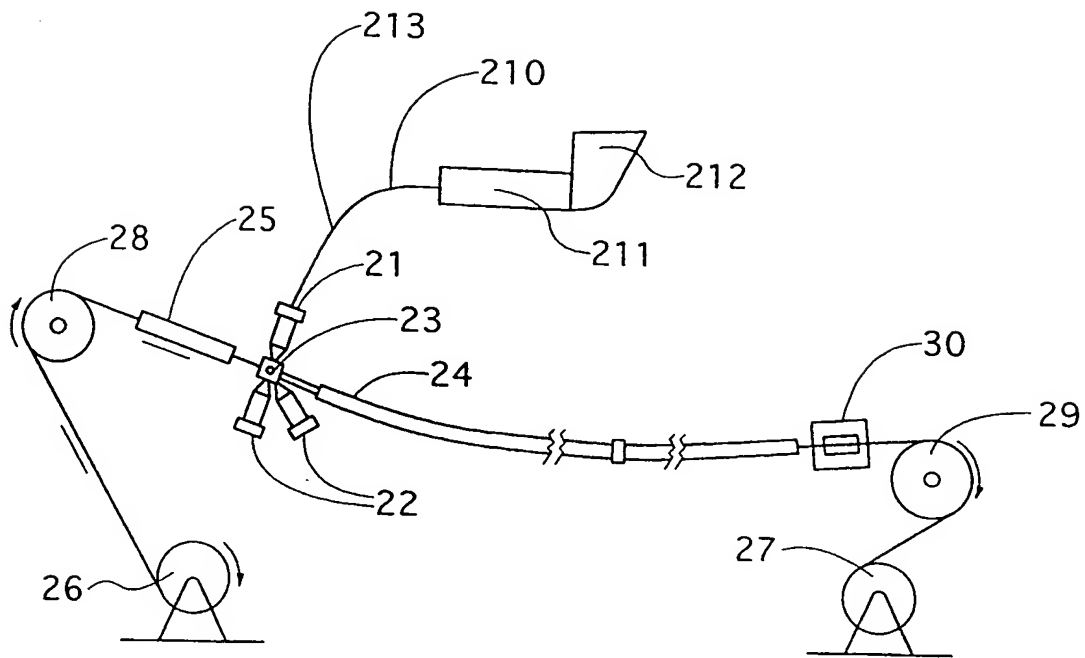


Fig 2

INTERNATIONAL SEARCH REPORT

Inter. Appl. No.

PCT/SE 99/00148

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H01B13/14 H01B3/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 065 504 A (FURUKAWA ELECTRIC CO LTD) 1 July 1981 see claims 1-14	1,8-11, 13
A	DE 35 38 527 A (SHOWA ELECTRIC WIRE & CABLE CO) 5 June 1986 see claims 1-11	1



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

28 May 1999

Date of mailing of the international search report

07/06/1999

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/SE 99/00148

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